ARS-52-6
JULY 1965

Selecting DUMP PITS and ELEVATOR LEGS for Country Grain Elevators

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PREFACE

This is the third of three related reports based on research to improve the design of commercial grain storages. The first was Marketing Research Report No. 387 (June 1960), "A Small Country Elevator for Merchandising Grain." The second was Marketing Research Report No. 671 (July 1964), "Selecting the Best Capacity of Truck Receiving Facilities for Country Grain Elevators." This report supplements Marketing Research Report No. 671.

The work was under the general supervision of Leo E. Holman, investigations leader, Transportation and Facilities Research Division, ARS.

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SELECTING DUMP PITS AND ELEVATOR LEGS FOR COUNTRY GRAIN ELEVATORS

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INTRODUCTION

Many combinations of dump pits and bucket elevators (legs) can be used at country grain elevators to receive the same amount of grain. The elevator manager usually has the choice of a large pit and a small-capacity leg or a small pit and a large-capacity leg.

This study was made to find the most economical combination of pit-leg capacities that would fit into the overall receiving capacity of the elevator. Results of a study on selecting the best overall receiving capacity for country grain elevators were published in Marketing Research Report No. 671, "Selecting the Best Capacity of Truck Receiving Facilities for Country Grain Elevators" (1).[1/]

METHOD OF STUDY

Combinations of dump pits and elevator legs were studied for two capacities of receiving facilities at country grain elevators. The low-capacity facility, as discussed in this report, is one in which the dump pit and the scale for weighing trucks are located together; the pit is about a foot behind the scale platform or even under the scale platform. The loaded truck is weighed, the grain is dumped in the pit, and then the empty truck is weighed--all in the same place. We have referred to this type of receiving facility as the scale-adjacent (fig. 1). At this type of facility, a two-man crew generally receives the grain--one man operates the scale and makes any necessary tests of the grain, and one man unloads the trucks.

For medium- or high-capacity receiving, the dump pit is usually removed from the truck scale about 200 feet (fig. 2). The 200-foot distance provides room for trucks to line up at the dump pit after being weighed.[2/] At this type of receiving facility, the loaded trucks are weighed, then driven to the dump

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1/ Underscored numbers in parentheses refer to items in the Bibliography.

2/ It is desirable that the scale be located reasonably close to the pit for easy movement of workers between them, but there should be plenty of room for trucks to wait at the pit. The scale does not have to be directly in line with the pit, as shown in figure 2. Sometimes the layout is arranged so the truck waiting line forms a large loop.

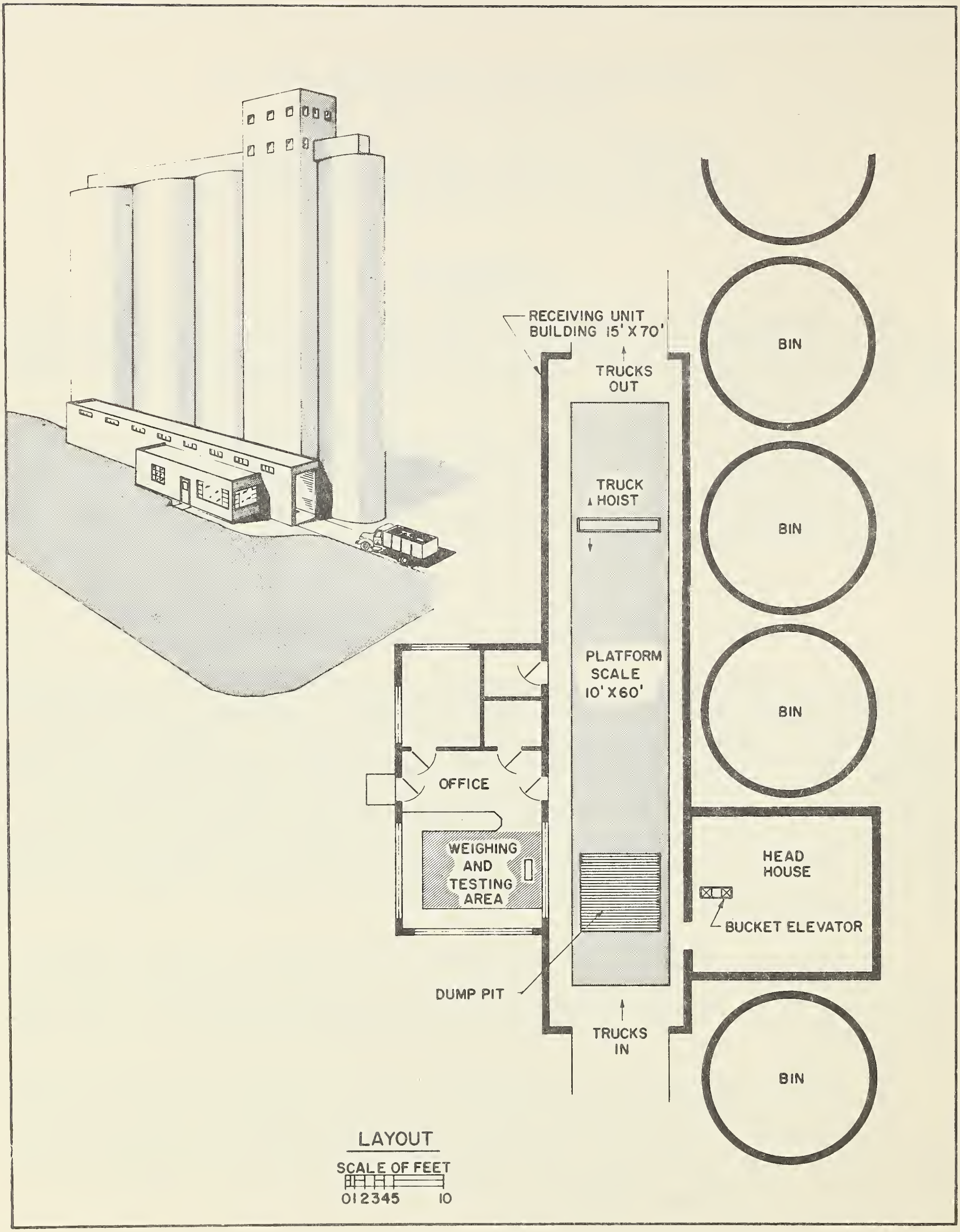

Figure 1.--A scale-adjacent type of receiving facility.

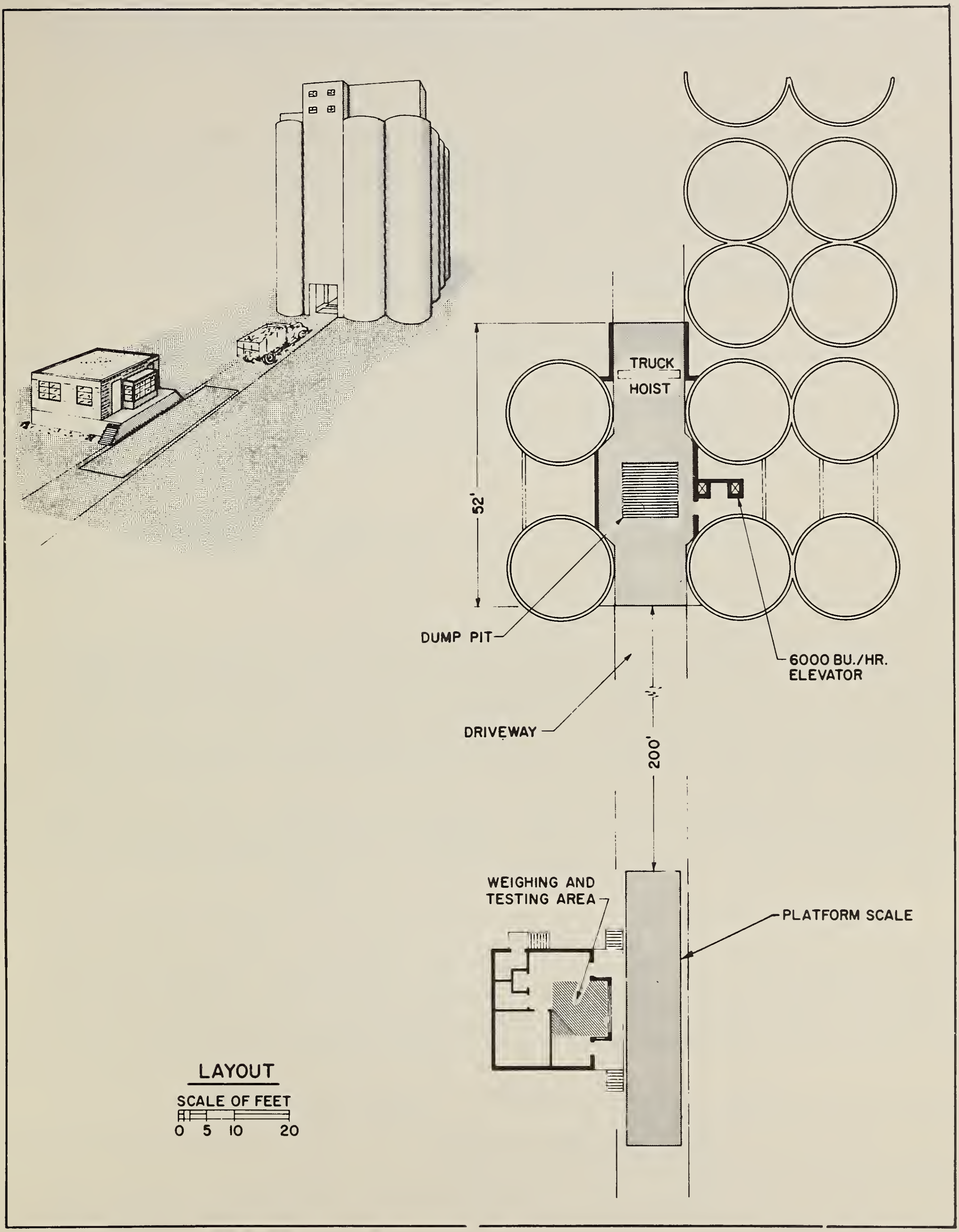

Figure 2.--A scale-separate type of receiving facility.

pit, where they are unloaded, and returned to the scale to be weighed empty. We have referred to this type of receiving facility as the scale-separate. There are usually two men at the scale and two men, or sometimes three, at the dump pit.

Two or three dump pits (each in a separate driveway and each served by a leg) are used at some elevators for faster unloading. At other elevators, each driveway has two pits, or one pit divided into compartments, served by one leg. At these elevators off-grade loads can be dumped into one of the pits or compartments so that such grain is separated from the rest of the grain. (See Discussion, page 11.) We studied receiving facilities having only one leg and one pit. A few elevators may have two legs as well as two pits in each driveway.

The maximum economical receiving capacities of these two types of receiving facilities were determined in a previous study (1). This capacity is the largest number of trucks the elevator can receive at harvesttime, without having trucks wait excessive times. (There is always some waiting time because trucks arrive at random intervals and the time required to service trucks varies; the elevator would have excessive receiving costs if the facilities were designed to eliminate all waiting.)

Based on arrival patterns of trucks in the Hard Winter Wheat area of the Central Great Plains and on service rates (the average number of grain trucks that can be received per hour), the scale-adjacent facility can economically handle a maximum of 600 trucks per harvest season.

During the wheat harvest season, which lasts from 10 days to 2 weeks, about 22 percent of the trucks (132 trucks) arrive in one day, and on this maximum day, about 10 percent (13 trucks) arrive in one hour. Typically, arrival rate is low during the early morning and builds up to a peak in the late afternoon. Most elevators are open about 16 hours a day during harvest to receive trucks.

The scale-separate facility can economically handle up to 1,450 trucks per harvest season. At this seasonal rate, the rate on the maximum day would be 319 trucks, and at the maximum hour, about 32 trucks.

Based on the number of trucks the elevator could handle if the trucks arrived at a steady rate, the average hourly receiving capacity of the scale-adjacent facility is 11 trucks or 2,200 bushels of grain. On the same basis, the average hourly receiving capacity of the scale-separate facility is 25 trucks or 5,000 bushels of grain. These average hourly receiving capacities are based on the following distribution of truck sizes and types:3/

Size of truck in bushels	Percent of trucks
Less than 50	0
50 to 99	7
100 to 149	18

3/ The distribution of truck sizes and types was determined from field observations made in Kansas.

Size of truck in bushels (cont.)	Percent of trucks
150 to 199	27
200 to 249	27
250 to 299	3
300 to 349	16
350 to 399	2
400 and above	0
	100

Type of truck	Percent of trucks
Self-dumping grain truck with sliding endgate	78
Standard farm grain truck:	
Sliding endgate	13
Removable endgate	4
Complete endgate	2
Pickup truck:	
Sliding endgate	2
Removable endgate	1
	100

This study of pit-leg combinations was based on the maximum daily arrival rates--132 trucks at the scale-adjacent receiving facility and 319 trucks at the scale-separate receiving facility. We assumed there is sufficient storage space to receive the grain as it comes off the elevator leg.

We used an elementary inventory model approach (fig. 3) to the problem (3, p. 199). Because trucks delivering grain arrive at random intervals during the hour, and because the time required to unload trucks varies with the type of truck, the supply of grain is variable. The constant speed of the leg produces a constant demand or flow of grain away from the pit. The inventory is the number of bushels of grain in the pit. An acceptable solution to the problem of pit-leg combinations must be one in which the supply never exceeds the demand to the extent that the inventory is larger than the pit capacity.

Five capacities of elevator legs were selected for the scale-adjacent facility and six capacities for the scale-separate facility. The movement of grain in and out of the pit was simulated numerically for a complete day's operation. The purpose of the calculations was to determine the capacity of pit that would not overflow with the capacity of leg selected.

For each of the pit-leg combinations, initial construction costs and annual ownership and operating costs were determined and evaluated.

The initial construction cost of dump pits was estimated at $2 per bushel of pit storage capacity.4/ In areas where there is unstable soil, rock, or a

4/ The capacity of the pit as used in this report is the number of bushels the pit can hold with the grain flowing to its natural angle of repose, with no leveling of the grain.

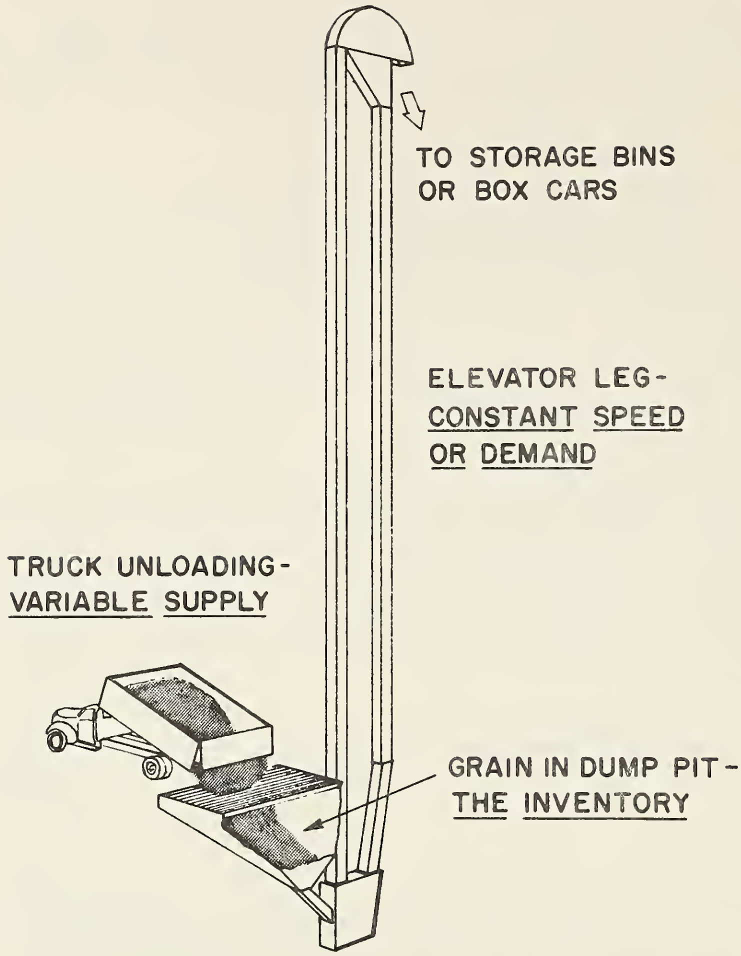

Figure 3.--The unloading operation.

high water table, the construction cost for pits could be much higher than $2 per bushel. The cost of the elevator leg was estimated at $2.30 per bushel per hour of capacity. This cost is based on an elevator height of about 150 feet, which is typical for many country grain elevators.

The annual rates used to determine ownership costs were:

Interest--6 percent of the average investment.
Depreciation of elevator leg--4.85 percent of the initial cost.
Depreciation of dump pit--2 percent of the initial cost.
Taxes--1.3 percent of the initial cost
Insurance--0.2 percent of the initial cost.

Details on ownership costs are given in tables in the section on calculations. For more discussion of the annual rates used and how they were determined, see Marketing Research Report No. 671 (1, p. 30). The difference in operating costs per bushel (maintenance and power) for the sizes of legs studied was not considered significant enough to include in this analysis.

RESULTS

Figure 4 shows the pit capacities required for the scale-adjacent receiving facility to handle 132 trucks per day for various elevator leg capacities. For example, with a 2,000-bushel-per-hour leg, one would need about an 800-bushel pit. Notice that for smaller dump pits (about 500 bushels or less), the capacity of the elevator leg increases rapidly as pit size decreases. Figure 5 shows the relationships between pit capacity and leg capacity for the scale-separate receiving facility.

Initial construction costs for the several combinations studied are shown in table 1. Annual ownership costs determined for the various pit-leg combinations are shown in figures 6 and 7. The lowest cost pit-leg combination for the scale-adjacent receiving facility is a 560-bushel pit and a 2,100-bushel-per-hour leg. For the scale-separate receiving facility, the most economical combination is a 1,300-bushel dump pit and a 4,900-bushel-per-hour elevator leg.

For both types of receiving facility, the leg capacity that is most economical is about 95 to 98 percent of the average hourly receiving capacity of the facility--a 2,100-bushel-per-hour leg for the receiving capacity of 2,200 bushels per hour, and a 4,900-bushel-per-hour leg for the receiving capacity of 5,000 bushels per hour. The economical pit size in bushels is about 25 percent of the leg capacity in bushels per hour.

DISCUSSION

Other factors besides ideal balance for unloading trucks at harvest may affect the selection of pit-leg capacities. First, there is often a minimum desirable capacity for both the leg and pit. For elevators that receive less than 500 or 600 trucks per harvest season, it is often the boxcar loading out operation and sometimes the grain turning operation that determines the capacity of the elevator leg (5). Most modern country grain elevators currently build legs with capacities of 4,000 bushels per hour or larger. Also, most operators want a dump pit that holds at least one truckload or about 300 bushels. Some elevators use the pit as a holding bin when loading boxcars. This requires a pit that will hold one boxcar load or 2,000 bushels.

However, for most large country elevators it is the truck receiving operation that determines the size of the leg and pit. The elevator manager should probably select equipment to match the maximum hourly receiving capacity he expects to have. Using a three-man crew to unload or dump trucks, for example, can increase the receiving capacity over the average used in this study. A three-man crew to unload trucks is about the largest practical size used.

The manager should avoid oversizing the leg. If all trucks had complete-opening endgates, were self dumping, and held 200 bushels, the unloading time would be 0.88 minute, or an unloading rate of 13,600 bushels per hour (4). This would probably be the largest leg capacity one would want to select. For the scale-separate receiving facility, where trucks are weighed independently of the unloading operation, unloading capacity must be coordinated with truck weighing capacity. Instead of enlarging elevator legs and dump pits, the

SCALE-ADJACENT RECEIVING FACILITY

Pit-Leg Combinations for 132 Trucks per Day

COUNTRY GRAIN ELEVATORS

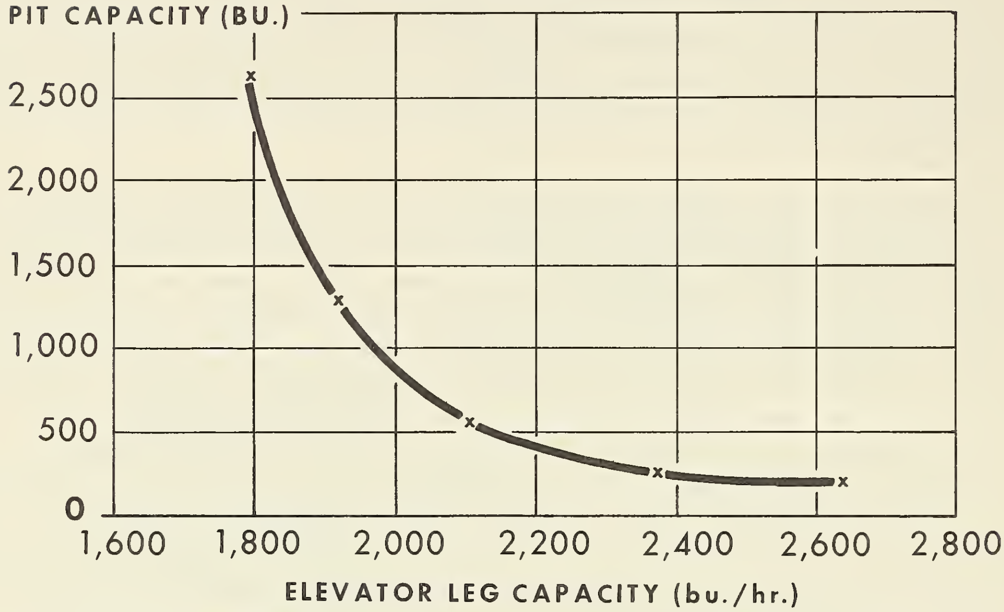

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Figure 4

SCALE-SEPARATE RECEIVING FACILITY

Pit-Leg Combinations for 319 Trucks per Day

COUNTRY GRAIN ELEVATORS

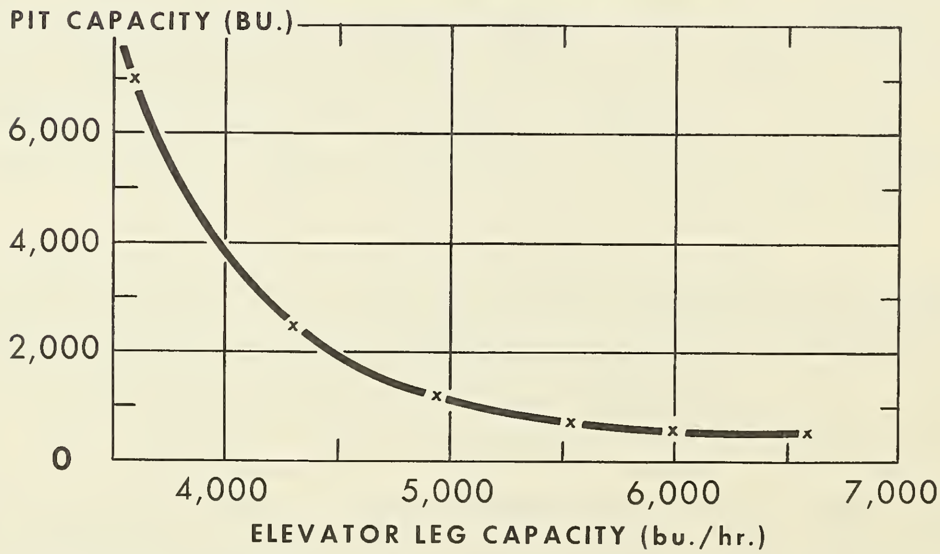

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Figure 5

Table 1.--Initial construction cost of various pit-leg combinations for receiving facilities at country grain elevators

[Based on maximum daily truck arrivals at harvesttime]

Type of receiving facility, maximum daily truck arrivals at harvesttime, and pit-leg combinations		Construction cost: Pit	Construction cost: Leg	Construction cost: Total
		Dollars	Dollars	Dollars
Scale-adjacent receiving facility, 132 trucks:				
Pit capacity in bushels	Leg capacity in bushels per hour			
243	2,640	486	6,072	6,558
299	2,376	598	5,465	6,063
560	2,100	1,120	4,830	5,950
1,290	1,920	2,580	4,416	6,996
2,611	1,800	5,222	4,140	9,362
Scale-separate receiving facility, 319 trucks:				
Pit capacity in bushels	Leg capacity in bushels per hour			
518	6,600	1,036	15,180	16,216
692	6,000	1,384	13,800	15,184
823	5,544	1,646	12,521	14,167
1,303	4,928	2,606	11,334	13,940
2,564	4,312	5,128	9,918	15,046
7,117	3,696	14,234	8,501	22,735

SCALE-ADJACENT RECEIVING FACILITY
Ownership Cost of Pit-Leg Combinations
COUNTRY GRAIN ELEVATORS

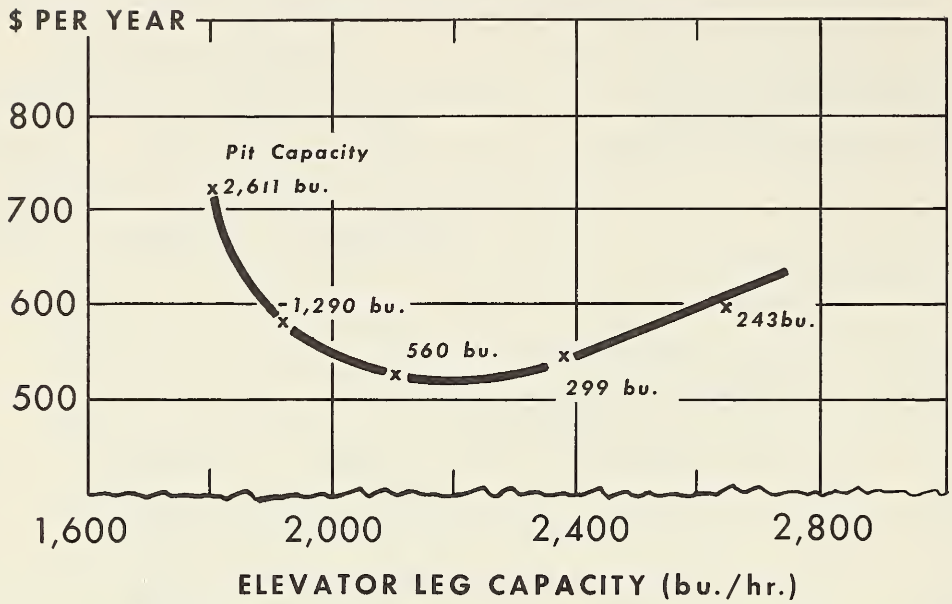

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Figure 6

SCALE-SEPARATE RECEIVING FACILITY
Ownership Cost of Pit-Leg Combinations
COUNTRY GRAIN ELEVATORS

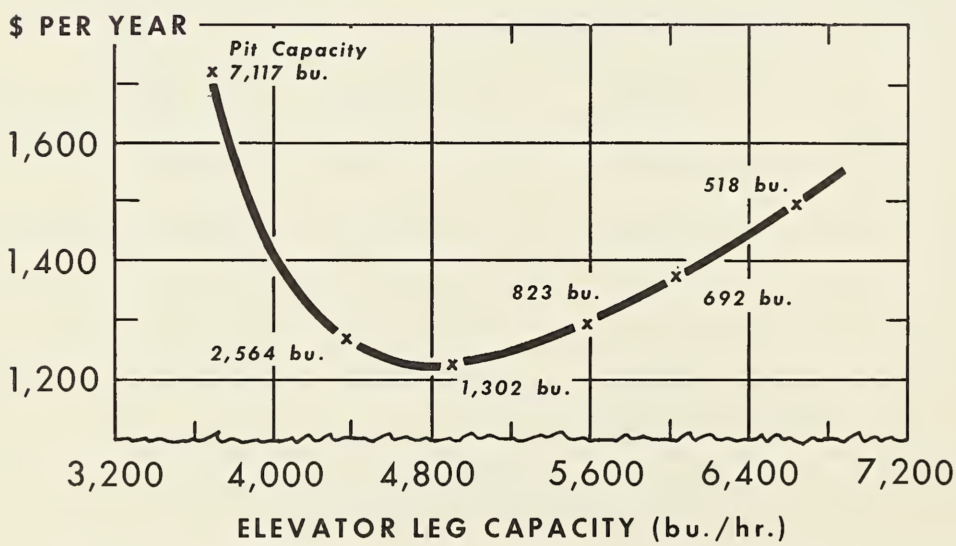

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Figure 7

manager should consider other ways of increasing the truck receiving rate and reducing waiting lines, such as the suggestions mentioned on page 43 of reference (1); for example, try to even out the arrival rates of trucks, change the working hours of the receiving crews to better fit the harvesting operation, and use pneumatic conveyors and other emergency unloading equipment.

The elevator manager may need to add extra capacity to the theoretical. Due to voltage drop in the power lines and resultant decrease in motor output, variations in methods of loading the buckets, and variations in the installation of the leg, a bucket elevator may sometimes operate well below the rated capacity.

For the ideally balanced pit-leg combination, as determined from figures 6 and 7, the capacity of the pit in bushels should be about one-fourth the capacity of the leg in bushels per hour. However, there are several reasons for building an oversized pit with an undersized leg or vice versa. With a large pit and small leg arrangement, some trucks can be received at the elevator without starting the elevator leg motor, and if there is a breakdown of the leg, a few trucks can still be received. If the arrival of trucks is very irregular or if many different types of trucks are used, this combination would be the most economical because the large pit can act as a surge or storage bin during slack periods. However, the large pit-small leg arrangement has this disadvantage: Different kinds of grain cannot be stored in the pit at the same time, so the pit must be completely emptied each time a different kind of grain is received.

On the other hand, there are certain advantages in building a small pit-large leg combination. This arrangement is particularly useful where the arrival rate is very regular and the same size and types of trucks are used. Then the need for a surge bin is small. Also, the small pit can be emptied in a hurry when other types of grain are received.

At some elevators, pits are divided into two or more compartments or two or more pits are built in each driveway. This is often done when the manager wants to separate the grain that may arrive during the same period on the basis of quality, variety, or moisture content. If the elevator receives only an occasional truck with off-grade grain during harvest, it is suggested that he build a primary pit of the size recommended in this study (about 25 percent of the leg capacity) and a secondary pit that will hold at least one truckload of grain. If the receipt of off-grade grain is more of a problem, a larger secondary pit would be required, its size depending on the distribution pattern of the receipts of off-grade grain. Some operators even use a separate driveway with pit and leg for handling separate grades.

If two pits in the same driveway are not required when the elevator is built, but two may be required in the future, it is usually a good practice to build the secondary pit initially, as well as to provide space for an installation of a second elevator.

APPLICATION OF RESEARCH RESULTS

To determine the best pit-leg combination for an elevator, the designer should go through calculations similar to those made in this study for his particular conditions. The following steps outline a simplified approximate method:

Steps	Example
1. Select an unloading rate to design for in terms of the maximum number of truck arrivals in any hour during the average or typical harvest (consider any future changes in truck arrival patterns). Results of a previous study (1) indicate that the unloading system can be most economically designed for about 70 percent of this maximum hourly arrival rate.[5]	Assume a maximum of 650 trucks per day with a maximum of 10 percent or 65 trucks arriving in an hour. Reduce this figure by about 30 percent for an economical design unloading rate-- 65 trucks per hour (t.p.h.) -19 (30 percent reduction) 46 t.p.h. design rate
2. Make a preliminary selection of the type and number of unloading units required. If the design rate found in Step 1 is 11 trucks per hour or less, the scale-adjacent type should usually be selected; if more than about 11 trucks per hour, select one scale-separate type unit for each 25 trucks per hour.	$\frac{\text{46 t.p.h.}}{\text{25 t.p.h. per unit}} = \text{1.8 units}$ Therefore, select 2 scale-separate type units.
3. Estimate the actual unloading capacity of the system based on types of trucks that will be received during harvest, and the size of unloading crew to be used. The 11 and 25 trucks per hour used in Step 2 are based on a 2-man crew and a distribution of trucks as shown on page 9. One can use the following information in estimating approximate unloading capacities:[6] a. A 3-man crew can unload about 10 to 30 percent faster than a 2-man crew. b. A self-dumping truck can be unloaded about 15 percent faster than a standard truck.	Assume there are more complete-opening endgate trucks than in the distribution on page 9; the actual unloading capacity for a 2-man crew, then, is about 27 t.p.h.

5/ When designing for corn harvest, where arrivals come in at a fairly even rate throughout the day, the design unloading rate should be based on as much as 100 percent of the maximum hourly rate.

6/ See Step B, page 38 of reference (1), for details on how to determine service rates for trucks.

Steps	Example
c. A complete-opening endgate truck can be unloaded about 40 percent faster than a sliding endgate truck.	
4. Re-estimate, if necessary, the type and number of unloading systems required, using the actual capacities found in Step 3.	$\frac{46 \text{ t.p.h.}}{27 \text{ t.p.h. per unit}} = 1.7$ units Two scale-separate unloading units will still be required.
5. Increase, if necessary, unloading capacity (Step 3) for maximum crew size to handle trucks in peak harvest years. Compare value found with design rate --Step 1.	27 t.p.h. + 3 (10% increase for 3-man crew) 30 t.p.h. For two units, 60 t.p.h. compared with the 46 t.p.h. found in Step 1.
6. Multiply figure selected in Step 5 by average size of truck.	30 t.p.h. x 200 bushels per truck = 6,000 bushels per hour (b.p.h.)
7. Multiply the value found in Step 6 by about 96 percent to find the capacity of the leg. Make the pit capacity in bushels about one-fourth the hourly capacity of the leg.	6,000 x 96 percent = 5,760 b.p.h. (Use about a 5,800 b.p.h. leg) 1/4 of 5,800 = 1,450 (Use about a 1,500-bushel pit)
8. Vary this combination if necessary in accordance with discussion on page 11-15.	

CALCULATIONS

The movement of grain in and out of the pit was simulated using a Monte Carlo technique (3). Table 2 shows a small portion of the simulation data for the scale-adjacent receiving facility with a 2,376-bushel-per-hour leg.

Column 2 shows when trucks move to the dump pit during the day.

The time between trucks (column 3) depends mainly upon the unloading rate of trucks during peak arrival periods. This in turn depends upon the type of truck endgate and the type of lifting mechanism.

The number of bushels brought in (column 4) depends upon the distribution of truck sizes.

The number of bushels taken out (column 5) depends upon the elevator leg capacity and the time between trucks. The difference between columns 4 and 5 is shown in column 6. The cumulation of column 6 is shown as the surge value or the amount of grain in the pit in column 7. The maximum value in column 7 would be the size of dump pit required so there would be no overflowing of grain.

Table 2.--A portion of the simulation data for the scale-adjacent unloading unit--elevator size = 2,376 bushels per hour or 39.6 bushels per minute

Truck number 1/	Time truck moves to unloading unit 2/	Time between trucks 3/	Bushels brought in (+) 4/	Bushels taken out (-) 5/	Difference between bu. in and bu. out 6/	Surge value 7/
	Minutes	Minutes	Bushels	Bushels	Bushels	Bushels
31	341.99	4.57	155	277.6	-122.6	0.0
32	349.00	7.01	160	224.5	- 64.5	0.0
33	354.67	5.67	308	224.5	+ 83.5	83.5
34	360.34	5.67	143	254.6	-111.6	0.0
35	366.77	6.43	228	293.4	- 65.4	0.0
36	374.18	7.41	207	151.3	+ 55.7	55.7
37	378.00	3.82	223	319.6	- 96.6	0.0
38	386.07	8.07	295	224.5	+ 70.5	70.5
39	391.74	5.67	187	110.1	+ 76.9	147.4
40	394.52	2.78	280	133.1	+146.9	294.3
41	397.88	3.36	138	133.1	+ 4.9	8/299.2
42	401.24	3.36	213	314.0	-101.0	198.2
43	409.90	7.93	167	190.5	- 23.5	174.7
44	414.71	4.81	370	339.4	+ 30.6	205.3
45	423.28	8.57	252	389.7	-137.7	67.6
46	433.12	9.84	235	264.9	- 29.9	37.7
47	439.81	6.69	199	521.5	-322.5	0.0
48	452.98	13.17	108	277.6	-169.6	0.0
49	459.99	7.01	133	162.8	- 29.8	0.0
50	464.10	4.11	150	206.3	- 56.3	0.0

1/ The first truckload arriving at the elevator in the morning is called truck number 1.

2/ From previous research data; this is taken from column T4 or T5D of the simulation data (1, p. 50). Truck 31 moves into the unloading unit 341.99 minutes after the start of the working day.

3/ The difference between arrival times in column 2.

4/ Random numbers were used to select truck size from distribution given on page 8.

5/ Capacity of elevator leg times column 3.

6/ Column 4 minus column 5.

7/ The number of bushels remaining in the pit.

8/ The maximum number of bushels in the pit.

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